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Station Bulletin 310 November, 1938

Vitamin "A" Requirements of Growing Chicks

A Review of Experimental Work

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A. E. Tepper and R. C. Durgin

THIS report covers investigations from 1931 to 1937 inclusive. The work of each of these six years is discussed as an individual experiment. The first four experiments—A, B, C and D—were conducted on a group basis but in Experiments E and F, recordings were made on the basis of individual chick action on birds maintained in individual cages.

Introduction

This report covers investigations from 1931 to 1937 inclusive. The work of each of these six years is discussed as an individual experiment. The first four experiments—A, B, C and D—were conducted on a group basis but in Experiments E and F, recordings were made on the basis of individual chick action on birds maintained in individual cages.

The objectives, in general, of the several tests were as follows:

1931-32 (1) To determine the efficiency of various levels of cod liver oil in the supply of an adequate amount of vitamin A to growing chicks; (2) to study the effect on growth of previously stored up vitamin A, if any, when the ration was later changed to a deficiency basis.

1932-33 (1) and (2) as in previous year; (3) the effect of increasing levels of cod liver oil for the supply of vitamin A as the age of chicks increases, and (4) the relative value of the New England College Conference ration from a vitamin A standpoint when fortified and when lacking in cod liver oil.

1933-34 (1) and (2) as in previous years; (3) the relative amount of vitamin A in sardine oil and its ability to prevent the occurrence of opthalmia.

1934-35 To determine the relative efficiency of California sardine oil as compared to cod liver oil from the standpoint of vitamin A supply when fed to growing chicks.

1935-36 To determine the optimum number of vitamin A units required by growing chicks up to six weeks of age.

1936-37 Same as in 1935-36.

Acknowledgment is here made of the work of H. O. Stuart and F. D. Reed, formerly of this station, and intimately associated with the early phases of vitamin A research at this institution.

Review of Early Literature*

Experimental evidence available up to the time of the institution of the reported projects on the subject of vitamin A requirements of chicks is at a minimum. Several workers have reported on phases rather closely allied to certain portions of the enclosed studies. Hart, Steenbock, Halpin and Johnston[6] have reported that a ration containing 72 per cent yellow corn as the chief source of fat-soluble vitamin A produces satisfactory growth. Hauge, Carrick and Prange[7] reported along similar lines, stating that 50 per cent yellow corn meal in a ration otherwise deficient in fat-soluble A meets the requirement for development of pullets up to the laying age.

In discussing the relation between the fat-soluble A vitamin and yellow pigmentation, Steenbock and Boutwell[16] state that these two factors are intimately associated in the maize kernel.

Mitchell, Kendall and Card[12] state that the growing chick has quite an intense requirement for vitamin A and that cereal grains must be supplemented by more concentrated vitamin sources. Their experiments also showed that a dietary deficiency of vitamin A will almost invariably lead to leg weakness in growing chicks.

Hauge, Carrick and Prange further state that chicks fed on rations deficient in fat-soluble A usually reflect such a deficiency in their growth response at almost four weeks of age.

Cruickshank, Hart and Halpin[3] observed kidney lesions in practically all of the birds that died during their experiment and tentatively concluded that the accumulation of urates in the ureters occurs only shortly before death. They further state that such kidney lesions; i. e. mottled appearance and accumulation of urates in ureters, were not entirely confined to a vitamin A deficiency. They report similar observed lesions in chicks suffering from coccidiosis.

Experiment A, 1931-32

Procedure

Nine groups of New Hampshire chicks were fed varying levels of cod liver oil standardized at a potency of at least 1,000 units per gram in addition to a basal ration deficient in vitamin A. Each group was subjected to irradiation from a uviare poultry treater at thirty inches distance for a period of fifteen minutes daily to supply a sufficiency of vitamin D.

Levels of one per cent to five per cent inclusive were used in addition to the control and reserve groups. The control group received the basal ration only, which was deficient in vitamin A, but they were subjected to ultra-violet treatment. No hard grains were fed to any of the groups throughout the 16 weeks of the experiment period.

Each group consisted originally of fifty day-old chicks except the reserve group which was started with one hundred chicks. This was made large so that we could separate at four weeks and at eight weeks two sizeable groups (25 chicks each) to be known as the 4-to-12 week control and the 8-to-12 week control, respectively. These groups received for

*Numbers refer to bibliography following text.

the first four weeks or the first eight weeks, according to respective lot, the regular reserve ration and were then changed to the vitamin A deficient or control ration. The object was to determine the effect on growth of previously stored up vitamin A, if any, when the ration was later changed to a deficiency basis.

The basal or control ration consisted of 140 pounds wheat bran, 140 pounds ground oat groats and 70 pounds of meat scrap. The reserve ration was the regular New England College Conference ration as recommended for starting and growing chicks and consisted of 200 pounds coarse yellow corn meal, 100 pounds wheat bran, 100 pounds wheat flour middlings, 100 pounds ground oats, 50 pounds meat scraps (50% protein), 25 pounds fish meal (at least 50% protein), 50 pounds dried skim milk, 25 pounds alfalfa leaf meal, 15 pounds calcium carbonate, 5 pounds salt and 1% of cod liver oil.

The records taken during the period covered (1) individual weight and gain figures weekly, (2) feed consumption weekly, (3) mortality, (4) microscopic examination of feces from each group and an autopsy regularly of one specimen of each group, (5) photographs of live specimens of each group, and (6) photographs of kidneys of these representative specimens. The tibia and femur bones of each bird so photographed were saved for a check on condition of calcification.

Discussion

In the analysis of the enclosed tables we find some very interesting data. In Table I, which shows the average weight per chick for each week in the several groups, we find that at sixteen weeks the reserve group was leading with a weight of 4.211 pounds per chick. The group on basal ration plus 3% cod liver oil was in second place with an average weight per chick of 4.031 pounds. The group weighing the least at the end of this period was the 1% cod liver oil group with an average weight per chick of 3.713 pounds.

If we study this table on the basis of twelve weeks, we find the reserve group again in the lead with an average weight per chick of 3.126 pounds. The 3% cod liver oil group again is second with an average weight per chick of 2.895 pounds. The lowest weight group, disregarding control groups, is the 5% cod liver oil group with an average weight of 2.627 pounds.

Then considering average weights from a basis of eight weeks, we note the same relation with the reserve group leading, the 3% cod liver oil group in second place and the 5% cod liver oil group the lowest in weight per chick. At the end of the four-week period the 1% cod liver oil group takes first place instead of the reserve group and the 5% cod liver oil group is again last.

With these placings in mind, two factors at once appear evident. First of all, since the group on the regular reserve ration led all others in growth for the sixteen-week period, it appears that vitamin A should be supplied through other sources besides cod liver oil alone. Secondly, there appears to be a definite requirement of vitamin A necessary for proper growth and nutrition as evidenced during this sixteen-week experimental period. In explanation of this last statement, notice in Table

EXPERIMENT A, TABLE I, Average weight, average feed consumption, efficiency of feed consumption, sex ratio, and mortality by groups.

Week	1% C. L. O.	2% C. L. O.	3% C. L. O.	4% C. L. O.	5% C. L. O.	Control 0-12 wks.	Control 4-12 wks.	Control 8-12 wks.	Reserve
				Average weight in pounds per chick					
Initial	.0936	.0908	.0908	.0891	.0906	.0894			.0903
1	.1401	.1327	.1252	.1280	.1300	.1468			.1300
2	.2297	.2228	.2014	.2061	.2088	.2476			.2204
3	.3919	.3758	.3447	.3571	.3327	.3580			.3731
4	.5639	.5612	.5157	.5353	.4921	.4767	.5532		.5510
5	.7919	.7932	.7507	.7700	.6836	.6677	.8088		.8054
6	1.011	1.040	.9780	.9960	.8821	.8833	1.053		1.084
7	1.293	1.309	1.298	1.286	1.159	1.144	1.326		1.386
8	1.580	1.580	1.606	1.581	1.437	1.219	1.568	1.565	1.601
9	1.911	1.901	1.968	1.917	1.745	1.302	1.939	1.933	2.043
10	2.233	2.174	2.312	2.242	2.065	1.345	2.280	2.243	2.389
11	2.504	2.423	2.611	2.538	2.371	1.405	2.577	2.479	2.732
12	2.761	2.729	2.895	2.780	2.627	1.581	2.778	2.671	3.126
13	3.125	3.199	3.567	3.130	3.125	D I S C O N T I N U E D			3.472
14	3.358	3.514	3.640	3.367	3.367				3.805
15	3.609	3.705	3.876	3.580	3.580				4.062
16	3.713	3.878	4.031	3.733	3.753				4.211
Ave.	18.507	18.178	18.062	17.038	18.281	7.424	10.045	6.067	22.411
Feed consumption									
To 12wk	3.79	3.83	3.61	3.73	4.04	4.70	4.51	5.48	3.88
To 16wk.	4.98	4.69	4.48	4.56	4.87				5.32
Feed consumed per pound gain									
Ratio of females to males	1:.46	1:.82	1:.76	1:.46	1:.70	1:.62	1:1.2	1:1	1:1.4
% Mort. Actual	5	12	18	20	24	66	12	4	15
% Mort. Corrected	3	10	8	16	20	63	12	4	3

I that the control group receiving no vitamin A was in the lead up to the third week. The lead was then taken by the 1% cod liver oil group and held until the fifth week when the 2% cod liver oil group was in the lead. At eight weeks the 3% cod liver oil group took the lead and held it until the end of the experimental period.

EXPERIMENT A, TABLE II, Leading groups according to weekly periods and their estimated vitamin A consumption

Week	Group	Feed consumption in pounds	Oil consumed in grams	Vitamin A units consumed
0—2	Control	.360	.000	———
3—4	1%	.935	4.26	4,261
5—7	2%	2.365	21.62	21,628
8—16	3%	14.835	202.94	202,942
Total		18.495	228.82	228,831

In way of explanation for the poor start of the reserve group, it should be said that a serious slip in brooding management was encountered and twelve chicks were lost the first week. This we believe to be the cause of the poor weight records for the first four weeks for this group.

In reference to the three control groups we note that the group which was started on a vitamin-deficient ration made good growth for two weeks, but from then on very poor gains were made and throughout the remaining twelve weeks it was the poorest group. At the age of four weeks this group showed evidence of weakness in its ability to stand and walk properly. Ruffed feathers also were apparent at this age.

The control group taken from the reserves at four weeks did well on the deficient ration for the first week only. After that it started to slide backwards and at twelve weeks was far behind the reserve group. In conjunction with this it was noticed that the yellow pigment disappeared after one week on the control ration.

With the 8-12 week control group similar effects were noticed. Not one week of their existence did they make as great a gain in weight per chick as did the reserve group. After three weeks on the vitamin A deficient ration, the yellow pigment disappeared.

From the actions of these three groups it appears that the baby chick absorbs enough vitamin A in the yolk at hatching time to fulfill its requirements for about two weeks. It also appears evident that there is a slight storage of vitamin A but not enough to fulfill the chick's requirements, as evidenced by the actions of the 4-12 and 8-12 week control groups as compared to that of the reserve group. Since the control group made good gains up to the third week; the 4-12 week control made a good gain for one week after being placed on a vitamin A deficient ration; and the 8-12 week control group did not gain so well as the reserve group during its existence—these facts are additional foundation for our previous statement, that there is a definite requirement for vitamin A as the chick's age increases. (Refer to Experiment E.)

Table I also presents the total feed consumption per chick for the entire experimental period. There appears to be very little difference in total feed consumption in the various groups receiving the basal ration plus

cod liver oil at different levels. The reserve group however, had a consumption per chick of approximately three pounds more than these oil groups.

When comparing the efficiency of these various rations in relation to pounds of feed consumed per pound gain in weight, as shown in Table I, we note that the 3% cod liver oil group was most efficient up to the 12-week period with a consumption of but 3.61 pounds of feed. The 4% cod liver oil group, the 1% cod liver oil group, the 2% cod liver oil, the reserves and 5% cod liver oil groups followed in the order named. For the 16-week period the 3 and 4% cod liver oil groups held the leads; and the 2% cod liver oil, 5% cod liver oil, 1% cod liver oil and reserve groups followed in the order named. Since the relatively higher level cod liver oil groups are more efficient in feed consumption as compared with the lower level groups our former statement appears to be again substantiated. There is apparently a greater requirement for vitamin A as birds approach maturity and the higher level cod liver oil groups seem to be satisfying that demand.

Table I lists the mortality on all groups for the entire experimental period. It is to be noted that as the percentage of cod liver oil fed increased, just so did the mortality. Too high content of cod liver oil appears to affect livability of chicks.

During the first few days of the experiment brooding difficulties were encountered which caused material loss in several groups. This loss, if disregarded, would show results not attributable to the effects of the feed mixture. Therefore, the column headed "corrected mortality" should be the figures applicable to the problem.

Specimens of each group were examined at regular intervals for evidence of vitamin A deficiency. At no time during the experimental period was any evidence found of vitamin A deficiency in the reserve group.

EXPERIMENT A, TABLE III, Estimated consumption of vitamin A by groups

Group	Grams oil consumed	Vit. A units consumed
1%	84.36	84,360
2%	168.72	168,720
3%	246.24	246,240
4%	310.38	310,580
5%	414.96	414,960

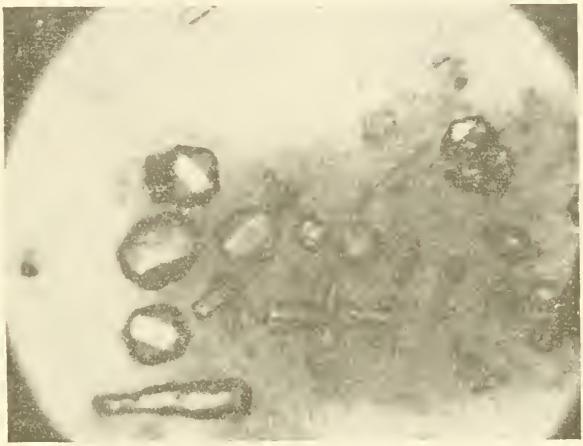
Up to three weeks of age no evidence was found of vitamin A deficiency in any of the groups. After this period however, material weakness of body control, ruffled feathers and crystals (see page 9) of an unknown nature found in the feces were observed for the control 0-12 week group. Slight kidney injury and presence of a very few crystals were observed in all the cod liver oil groups at varying periods. There did not seem to be any material difference in quantity of crystals observed in these groups. The types of crystals varied in shape.

No evidence of opthalmic infection of eyes or presence of lesions in mouth or pharynx was observed up to six weeks in any of the groups. However, at eight weeks the control groups showed material evidence of an opthalmic condition. Eyes were swollen, watery and an exudate of

a cheesy-like consistency was present in the corners of the eyes. Mortality was very heavy. The kidneys appeared grayish in color with swelling. The ureters were very much enlarged.

Efforts to isolate from the kidneys and ureters crystals similar to those found in the feces and in scrapings from the large intestine and caeca were fruitless.

Although crystals in the feces and intestinal scrapings were observed in all cod liver oil groups from 4-12 weeks of age, none were found at 16 weeks of age.



Microscopic crystals observed in fecal material and in scrapings from intestines.

Experiment B, 1932-33

Procedure

An indication in last year's work on this project that there was an increasing demand for vitamin A by growing chicks as they approach maturity led us to include an additional experimental group (Group X). This group was fed a basal ration deficient in vitamin A plus varying levels of cod liver oil of known vitamin A potency as the age increased. For the first two weeks no addition of vitamin A through the medium of cod liver oil was made. During the third and fourth weeks 1% of cod liver oil was fed; 2% for the fifth, sixth and seventh weeks; and from then to the end of the 12 weeks experimental period the level was increased to 3%.

In comparison with this group were five others which were handled in the same way as last year. These groups being fed the basal ration consisting of 140 pounds wheat bran, 140 pounds ground oat groats, and 70 pounds meat scrap, plus levels of standardized cod liver oil ranging from 0% to 3%. The group receiving the regular New England College Conference ration was held as a check pen.

In addition to these six groups of 50 New Hampshire Red chicks each, it was thought desirable to compare the growth of chicks being fed the New England College Conference ration and those receiving this ration minus the cod liver oil. By so doing, the value of this ration from a vitamin A standpoint when lacking in cod liver oil could be roughly estimated.

EXPERIMENT B, TABLE IV, Average weight, average feed consumption, efficiency of feed consumption, sex ratio, and mortality by groups

Weeks	1% C. L. O.	2% C. L. O	3% C. L. O.	Control 0-12 wks.	Reserve	Control 4-12 wks.	Control 8-12 wks.	Reserve Minus C. L. O.	Group X
				Average weight in pounds per chick					
Initial	.0860	.0876	.0858	.0852	.0933			.0852	.0908
1	.1245	.1253	.1262	.1312	.1358			.1306	.1331
2	.2215	.2293	.2185	.2464	.2372			.2282	.2348
3	.3595	.3816	.3322	.3646	.3609			.3671	.3789
4	.5497	.5348	.4920	*.3916*	.5412	.5334		.5395	.5623
5	.7361	.7442	.7058	.4733	.7603	.7616		.7430	.7834
6	1.002	1.044	.9411	.6783	1.045	1.106		.9782	1.058
7	1.313	1.361	1.217	.980	1.275	1.373		1.273	1.333
8	1.638	1.698	1.490	1.290	1.575	1.717	1.624	1.550	1.618
9	1.892	1.967	1.820	1.624	1.901	2.063	1.987	1.782	1.863
10	2.239	2.311	2.121	1.994	2.172	2.433	2.348	2.073	2.208
11	2.620	2.669	2.468	2.375	2.499	2.715	2.832	2.393	2.579
12	2.842	2.941	2.719	2.592	2.741	2.872	3.016	2.607	2.826
Ave. feed consumption	10.933	11.570	9.834	11.288	10.458	10.464	5.632	11.060	10.385
Feed consumed per pound gain	3.84	3.93	3.62	4.35	3.81	....	..	4.24	3.67
Ratio of Sexes	1:.73	1:.94	1:1.62	1:1	1:.93	1:.85	1:1.77	1:.85	1:.95
% Mortality	0	2	10	76	8	4	0	2	2

—— This group showed 76 per cent mortality at this period. Ninety-six grams of cod liver oil with potency of 2,000 vitamin A units per gram were fed. Assuming equal consumption per chick, then 16,000 vitamin A units were consumed per chick. No mortality occurred after this date and opthalmia disappeared.

Since the vitamin D content would be a variable also under these conditions all groups were subjected to irradiation by an ultra-violet ray lamp for a period of fifteen minutes daily throughout the course of the experiment.

All chicks were wingbanded and individual weights were taken each week for the 400 chicks. Feed consumption and mortality figures were also recorded. All dead chicks were autopsied and reports held for reference.

During the course of the experiment representative specimens from each group were removed for autopsy for determination of presence or absence of vitamin A deficiency.

Sex determination of chicks in each group was made at the age of eight weeks in order that we could determine influence of sex on results such as weight, growth and feed consumption.

Discussion

In the analysis of Table IV on average weight records per chick for the various groups, we find at the end of the twelve-week experimental period a difference between high and low groups of only .424 pounds, less than one-half pound. With such a small difference in weight between groups definite conclusions are difficult as to the better level of cod liver oil to feed or the number of vitamin A units required. Of the groups receiving various levels of cod liver oil, the 2 per cent group led in weight gains at the end of the experiment.

The control 0-12 weeks group showed definite symptoms of vitamin A deficiency at the age of three weeks. Autopsy findings noted diseased kidneys, grayish in color; enlarged ureters; urinary crystals present in fecal material of the large intestine; and watery and swollen eyes. In some cases a complete closing of the eye occurred.

In comparison of mortality as shown in the same table we note considerable increase as the content of cod liver oil in ration was increased. The 1% cod liver oil group suffered no mortality, the 2% cod liver oil group showed 2 per cent mortality, while the 3% cod liver oil group had 10 per cent mortality for the twelve-week period.

The feed consumption for all groups varied considerably by weekly periods but the total consumed per chick per group as computed at the end of the experiment, differed by approximately one and one-half pounds between high and low groups. The 3% cod liver oil group consumed the least amount of feed, 9.834 pounds per chick, and were most efficient, in regard to feed consumed per pound of gain, 3.62 pounds. The 2% cod liver oil group consumed 11.5 pounds of feed per chick and used 3.93 pounds of feed per pound of gain. The reserve group consumed 10.458 pounds of feed per chick and needed 3.81 pounds to produce a pound of gain up to 12 weeks.

The groups known as control 4-12 weeks and control 8-12 weeks, which had received a ration adequate in vitamin A for the first four and eight weeks respectively and then were fed a ration deficient in vitamin A, were slower showing the effects than in the previous year's work. Both groups made greater gains after being placed on the vitamin A deficient ration than did the reserve group from which they were taken. However, the

last week, these groups showed a materially reduced gain in weight. This sustained growth may have been due to a greater intake of vitamin A during the first four or eight weeks. An oil of greater potency per gram was used this year than last year, i. e., standardized to contain at least 2,000 U.S.P. units per gram.

Reserve versus Reserve No Oil

A comparison of these two groups of chicks (Table IV) shows a slight difference in weight, only .134 pounds, in favor of the reserve group. The feed consumption per chick for the twelve-week period is also favorable to the reserve group with a lower feed intake of .602 pounds per chick than the group receiving the reserve ration without cod liver oil. Only 3.815 pounds of feed were required to produce one pound of gain up to twelve weeks for the reserve group whereas the group receiving no cod liver oil required 4.242 pounds of feed to produce a pound of gain.

The mortality record shows but 2 per cent loss in twelve weeks for the group receiving no cod liver oil while the chicks on the Reserve ration with 1% cod liver oil showed a mortality of 8 per cent.

Neither group showed any evidence of a vitamin A deficiency and from these results a tentative conclusion is that there is enough vitamin A in the New England College Conference ration without the addition of cod liver oil to prevent opthalmia under the conditions of this experiment.

Increasing Levels of Vitamin A

In reviewing the results obtained by feeding chicks increasing levels of vitamin A through the medium of a standardized cod liver oil, we find very little difference between that and feeding from the start a level of either 1% or 2% cod liver oil.

The final weight per chick of 2.826 pounds compared favorably with the group receiving 1% cod liver oil with a weight of 2.842 pounds. The difference in weight is not significant.

Mortality of two per cent is quite favorable but the same mortality percentage was secured by the group receiving 2% cod liver oil plus the basal ration.

Since the results secured from feeding increasing levels were no better than through the feeding of a set level of either 1% or 2% of cod liver oil throughout the experimental period, the extra effort and cost expended for labor is not warranted.

EXPERIMENT B, TABLE V, Estimated consumption of Vitamin A by groups as received through cod liver oil

Group	Vitamin A units consumed
1% C. L. O. plus basal ration	99,408
2% " " " "	211,036
3% " " " "	269,040
Control 0-12 weeks	None up to 5 weeks
Reserve	94,848*
Control 4-12 weeks	9,120
Control 8-12 weeks	29,184
Group X	238,000
Reserve minus C. L. O.	None*

*These groups received vitamin A through feed ingredients contained in ration other than cod liver oil.

Experiment C.—1933-34

Procedure

This experiment involved the use of eleven groups of 50 New Hampshire Red chicks, or a total of 550 chicks. The test groups were fed in growing batteries as follows:

1. Basal ration—deficient in vitamin A
   140 pounds wheat bran
   140 " ground oats
   45 " meat scraps (50% protein)
2. Basal + 1% cod liver oil
3. Basal + 2% cod liver oil
4. Basal + 3% cod liver oil
5. 4-12 week control
   (25 chicks from Group 9 were removed at end of four-week period and fed only basal ration from then till end of period.)
6. 8-12 week control
   (25 chicks from Group 9 were removed at end of eight-week period and fed only basal ration from then till end of period.)
7. Basal ration for first two weeks and then basal ration plus 1% cod liver oil.
8. Basal ration plus 1/2% sardine oil.
9. New England College Conference ration (check group).

All chicks were wingbanded and weighed individually by weekly periods with sex notation being made as soon as possible for subsequent weight and growth analyses. Feed consumption was recorded weekly. All mortality was tabulated and autopsy records preserved for analysis.

Groups 1 to 8 inclusive were treated daily with ultra-violet light for a period of 15 minutes at 30 inches distant. This provision was made to furnish a supply of vitamin D to all groups above their normal requirements.

Group 8 was used to determine the relative amount of vitamin A in sardine oil and its ability to prevent the occurrence of opthalmia.

Discussion

Group 1 showed materially slower growth and presence of a vitamin A deficiency was noted in all chicks but one. Swelling of the eye and some indications of watery eyes were present at four weeks of age. A few chicks which died between nine and ten weeks of age exhibited heavy urate deposits over kidneys which were themselves grayish in color. Nodules in throat and esophagus were found in two chicks upon autopsy.

Groups 2, 3 and 4 showed very little difference in weight gains indicating that the 1% cod liver oil supplied sufficient vitamin A both for prevention of opthalmia and optimum growth. Additional amounts were not used more efficiently when comparing growth and freedom from vitamin A deficiency.

Group 9 (check) receiving the New England College Conference ration weighed at the end of the twelve-week period 2.897 pounds per chick average. This was approximately one-half pound heavier average per chick than the 1, 2, or 3% cod liver oil groups on basal ration.

The 4-12 week control group, No. 5, showed continued normal gains up

to the eighth week. After this time the growth rate was reduced and the final weight at twelve weeks showed a loss over the weight at eleven weeks of age. This indicates that there was apparently enough storage of vitamin A for about four weeks of normal growth. After this period the demand for vitamin A was in excess of the body supply.

EXPERIMENT C, TABLE VI, Average weight in pounds per chick of the various groups by weekly periods

	Group								
Week	1	2	3	4	5	6	7	8	9
Initial	.0876	.0872	.0890	.0880			.0888	.0878	.0891
1	.1029	.1142	.1114	.1108			.1169	.1169	.1268
2	.1710	.1843	.1851	.1765			.1837	.1891	.2094
3	.2435	.2811	.2556	.2583			.2245	.2443	.3228
4	.3419	.3981	.3583	.3571	.4860		.3363	.3214	.4632
5	.4678	.5969	.5265	.5079	.6150		.5151	.4750	.6872
6	.5582	.8033	.6921	.6786	.8280		.7300	.6687	.9185
7	.6595	.9616	.9041	.9380	1.045		.9568	.8500	1.194
8	.7866	1.286	1.163	1.202	1.337	1.418	1.277	1.118	1.498
9	.9597	1.521	1.407	1.489	1.585	1.720	1.591	1.378	1.867
10	1.066	1.786	1.725	1.738	1.730	2.043	1.926	1.611	2.231
11	1.205	2.083	1.984	2.117	1.878	2.303	2.283	1.875	2.605
12	1.217	2.397	2.322	2.398	1.864	2.552	2.588	2.097	2.897

Group 6, known as 8-12 week control group, after being removed from Group 9 at eight weeks of age, showed continued gains. The rate of growth, however, was somewhat less than that of Group 9. The demand for vitamin A after the eight-week period seems to be in excess of the amount stored up and may be the result of the reduced body gains.

Group 7 which received no vitamin A supply during the first two weeks of life, but received 1% oil in the basal ration from 3 to 12 weeks of age showed better weight gains than did Group 2. Group 2 received 1% cod liver oil plus basal ration for entire period. There was, however, between the ages of two and seven weeks a slackening of weight gains as compared to Group 2. It should be stated that the sex ratio of males to females in Group 2 was 1:1.9 and that in Group 7 was 1:1.

EXPERIMENT C, TABLE VII. Feed consumption per chick per week for all groups

Week	1	2	3	4	5	6	7	8	9
1	.085	.078	.082	.115			.093	.095	.095
2	.186	.207	.217	.168			.191	.228	.207
3	.261	.316	.292	.287			.352	.269	.308
4	.378	.420	.348	.370			.352	.248	.405
5	.616	.642	.551	.500	.600		.579	.518	.613
6	.621	.827	.719	.697	.860		.863	.712	.738
7	.865	.982	.640	.965	1.220		1.022	.900	1.014
8	.712	1.130	1.323	1.048	1.360		1.238	1.012	1.132
9	.875	1.357	1.365	1.211	1.367	1.364	1.693	1.080	1.232
10	.972	1.333	1.350	1.113	1.625	1.500	1.488	1.342	1.433
11	.950	1.850	1.516	1.637	1.166	1.282	1.670	1.555	1.559
12	.866	1.711	1.650	1.258	1.208	1.304	1.556	1.430	1.672
Total:	7.417	10.883	10.056	9.669	9.406	5.450	11.097	9.519	10.438
Feed per lb. gain	6.09	4.54	4.33	4.032	6.82	4.93	4.28	4.53	3.60
Ratio of males to females	1:1.3	1:1.9	1:.87	1:1.9	1:2.43	1:1.55	1:1	1:1.4	1:.61

Apparently the reserve supply of vitamin A in the baby chick upon hatching was materially reduced during the first two weeks of life. Following this period five weeks were used to secure from the 1% cod liver oil ration enough vitamin A to replenish the reserve supply and to continue growth with more normal gains. By the actions of this group there is indicated a method of determining vitamin A transfer from the breeder to the baby chick based on livability and growth.

Group 8, fed the basal ration plus ½% sardine oil, showed slightly less weight gains than did the cod liver oil groups. The final average weight per chick at the end of the twelve-week period was 2.097 pounds as compared with the 1% cod liver oil fed group of 2.397 pounds. At no time during the course of the experiment were there any symptoms of a vitamin A deficiency.

In the analysis of Table VII there is indicated a direct relationship between Groups 2, 3, and 4 in both total feed consumption and in feed consumption per pound of gain. The group receiving 3% cod liver oil plus the basal ration was more efficient in feed consumption as evidenced by gain in weight than were the lower cod liver oil fed groups. The order of efficiency is approximately the same as that evidenced in previous years' tests. The check group receiving the New England College Conference ration was the most efficient with but 3.6 pounds of feed per pound gain up to twelve weeks of age.

EXPERIMENT C, TABLE VIII. Mortality

	Number	Per cent	Major cause
Group 1	20	40.0	Vitamin deficiency
Group 2	8	16.0	Pneumonia
Group 3	8	16.0	"
Group 4	13	26.0	"
Group 5	1	4.0	"
Group 6	1	4.0	"
Group 7	10	20.0	"
Group 8	10	20.0	"
Group 9	5	10.0	"
Average for all lots		17.3	

It is to be noted in Table VIII that Group 4, receiving the high level of cod liver oil (3%) had a very high mortality. Previous years' tests have indicated that too high content of cod liver oil in feed affects livability of chicks adversely.

Experiment D—1934-35

Procedure

To determine the relative efficiency of California sardine oil and cod liver oil from the standpoint of vitamin A supply, a feeding test using New Hampshire Red chicks was started March 7, 1935.

Six groups of thirty chicks each were raised in batteries over an experimental period of twelve weeks. The basal ration consisting of 140 pounds wheat bran, 140 pounds ground oats, and 45 pounds meat scraps was fed to five groups plus a specified amount of cod liver oil or sardine oil. The basal ration, which is deficient in vitamin A, was thus fortified with varying amounts of this vitamin from the two fish oil sources.

In order that the vitamin D requirement be fully supplied, these five groups received daily ultra-violet irradiation from a mercury vapor lamp for a period of fifteen minutes at a distance of thirty inches.

Group 1 was fed the basal ration which is deficient in vitamin A. Group 2 received the basal ration plus the addition of ½% cod liver oil, standardized to contain at least 2.000 units of vitamin A per gram. Group 3 was fed the basal ration plus one per cent cod liver oil. Group 4 received the basal ration plus ½% sardine oil. Group 5 was fed 1% sardine oil in addition to the basal ration. Group 6, used as a check group, was fed the regular New England College Conference ration adequately balanced in all known respects.

At the start of the experiment all chicks were wingbanded and individually weighed. These weighings were continued weekly for later weight and growth comparison. Group feed consumption records were computed weekly and autopsy records secured for all chicks which died during the course of the test.

Discussion

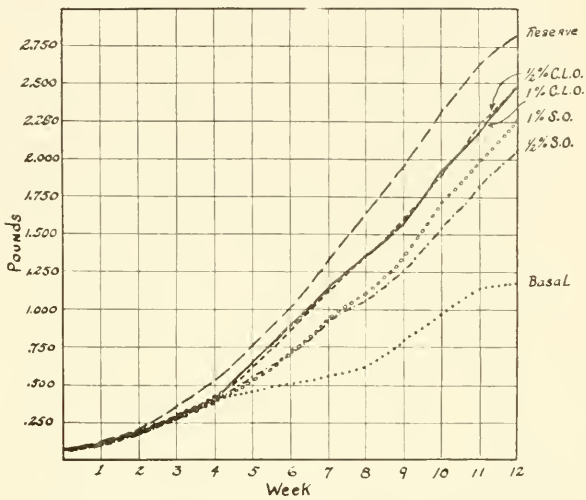
A study of Table IXA and B, presenting the average feed consumption per chick for the 12-week period, shows that the groups which received cod liver oil in addition to the basal ration consumed more feed than did those receiving sardine oil. Group 2 consumed 10.945 pounds per chick for the twelve-week experimental period; Group 3 consumed 10.926 pounds, Group 4 consumed 9.529 pounds and group 5 consumed 9.448 pounds.

In a computation to determine the relative efficiency of feed consumption based on weight gains we find a somewhat different relationship. Group 6 which received the New England College Conference ration was most efficient in this respect. The consumption of feed for this group was

EXPERIMENT D, TABLE IX-A. Average weight, feed consumption, efficiency of feed consumption and mortality for all groups.

	Basal			½% cod liver oil			1% cod liver oil		
Week	Male	Female	Average	Male	Female	Average	Male	Female	Average
	Average weight, in pounds, per chick								
Initial	.0941	.0990	.0967	.0933	.0928	.0930	.0956	.0950	.0953
1	.1300	.1235	.1267	.1255	.1157	.1206	.1243	.1292	.1267
2	.2133	.1921	.2027	.2111	.1727	.1919	.1918	.1991	.1954
3	.3022	.2723	.2872	.3200	.2817	.3023	.3193	.3150	.3171
4	.3700	.3425	.3562	.4311	.3958	.4134	.4025	.4000	.4012
5	.4533	.4537	.4535	.6844	.5711	.6277	.6693	.6291	.6492
6	.4877	.5185	.5031	.9166	.7800	.8633	.9493	.8308	.8900
7	.5277	.6071	.5674	1.243	.9962	1.1196	1.229	1.075	1.152
8	.5883	.6828	.6356	1.524	1.211	1.369	1.462	1.258	1.360
9	.9150	.6885	.8017	1.777	1.423	1.600	1.730	1.454	1.592
10	1.1000	.8257	.9628	2.075	1.743	1.909	2.101	1.766	1.933
11	1.380	.9440	1.1620	2.417	2.030	2.223	2.376	1.980	2.178
12	1.460	.9225	1.1912	2.688	2.246	2.467	2.720	2.229	2.474
Ave. feed consumption			6.334			10.945			10.926
Feed consumed per pound gain			5.317			1.436			4.416
% mortality			83.3			16.6			6.6

3.931 pounds per pound of body gain for the experimental period. Group 5, receiving the basal ration plus 1% sardine oil, was second with a feed consumption of but 4.190 pounds. Group 3 consumed 4.416 pounds;



Experiment D, comparative growth chart, 1934-35.

Group 2 consumed 4.436 pounds and Group 4 consumed 4.550 pounds of feed per pound gain in weight. The vitamin A deficient group consumed 5.317 pounds and was the least efficient.

The tables also present the weight records of males, females and group averages for the various lots. Of the comparative oil groups, Group 3 receiving basal ration plus 1% cod liver oil leads with an average weight of 2.474 pounds per chick. Group 2 follows with 2.467 pounds, Group 5

EXPERIMENT D, TABLE IX-B, Average weight, feed consumption, efficiency of feed consumption and mortality by groups.

	1/2% sardine oil			1% sardine oil			Reserve		
Week	Male	Female	Average	Male	Female	Average	Male	Female	Average
	Average weight, in pounds, per chick.								
Initial	.0920	.0910	.0915	.0921	.0931	.0926	.0929	.0923	.0926
1	.1170	.1122	.1146	.1207	.1143	.1175	.1211	.1191	.1201
2	.1780	.1818	.1799	.1871	.1780	.1826	.2135	.2075	.2005
3	.2890	.2775	.2832	.2792	.2686	.2739	.3747	.3541	.3644
4	.3930	.3762	.3846	.4157	.3940	.4048	.5794.	.5366	.5580
5	.5860	.5287	.5573	.5600	.5246	.5423	.7882	.7408	.7645
6	.7570	.6593	.7081	.7464	.6753	.7108	1.104	1.001	1.052
7	.9630	.8633	.9131	.9757	.8553	.9155	1.425	1.264	1.344
8	1.129	1.038	1.083	1.211	1.035	1.123	1.757	1.545	1.651
9	1.316	1.221	1.268	1.489	1.246	1.368	2.071	1.838	1.954
10	1.642	1.469	1.556	1.852	1.570	1.711	2.486	2.179	2.332
11	1.941	1.734	1.837	2.136	1.805	1.970	2.856	2.412	2.634
12	2.238	1.948	2.093	2.475	2.053	2.264	3.073	2.566	2.819
Ave. feed consumption			9.529			9.448			11.083
Feed consumed per pound gain			4.550			4.190			3.931
% mortality			16.6			3.3			6.6

averaged 2.264 pounds. Group 4 weighed 2.093 pounds, and Group 1 averaged but 1.1912 pounds. At the twelfth week weighing only five chicks remained in Group 1.

It is evident from these results that although the cod liver oil fed groups were slightly heavier than the sardine oil fed groups, the latter made substantial gains over the experimental period.

There was no significant difference in mortality between comparative groups. It is interesting to note that both oil groups at the 1/2% level had a rather high mortality of 16.6 per cent. There were no deaths caused by a vitamin A deficiency in any of the oil fed groups. Apparently the sardine oil as used in this test when fed at either 1/2% or 1% level supplied sufficient vitamin A to prevent death directly attributable to such deficiency.

The group receiving the deficient ration showed a mortality of 83.3 per cent. There was considerable variation between individuals in their ability to withstand a deficiency in vitamin A.

Experiment E—1935-36

Procedure

Individually pedigreed sex-linked pullets from Barred Rock-New Hampshire crosses were maintained in 20 individual cages starting as day-olds April 16, 1936, and extending over a period of six weeks. Twenty chicks were divided into five groups of four chicks each. The estimated daily vitamin A unit consumption by groups was as follows:

Group 1 Basal ration
Group 2 Basal ration plus 33 U.S.P. X (1934) A units
Group 3 Basal ration plus 99 " " " " "
Group 4 Basal ration plus 165 " " " " "
Group 5 New England College Conference formula

The basal ration fed to the first four groups consisted of 46 pounds white corn, 20 pounds ground wheat, 5 pounds wheat bran, 15 pounds dried skimmilk, 10 pounds meat scraps, 1 pound sodium chloride, 2 pounds calcium carbonate and 1 pound irradiated yeast 400,000 U.S.P. vitamin D units per pound. The vitamin A supply to groups 2, 3 and 4 was administered daily by means of a graduated pipette, using a commercial pro-vitamin A carotene solution, analyzing 1,500,000 U.S.P.X (1934) units per pound. Daily feed consumption and body weight records were obtained as indicated.

Discussion

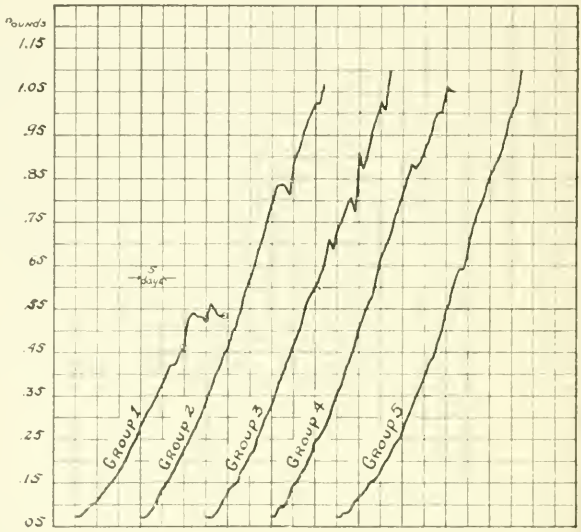
By a study of the comparative growth rates of the five lots of chicks on test, (Table X) it is noticed that there is a relatively high demand for vitamin A by growing chicks during the primary stages of growth. The lead in growth or weight of chicks established by the group fed 165 U.S.P. X (1934) vitamin A units per day was maintained up until the fifth week. At this time the rate of growth slowed to some extent and the lower vitamin A fed groups rapidly made up the relatively small difference in weight. Groups 2 and 3 exceeded group 4 in average weight per chick by a slight margin at the end of the experimental period with group 3 leading at 1.102 pounds per chick. The differences, however, are so small as to be of no significance.

The total feed consumed by groups showed a rather definite relationship to the amount of vitamin A fed. Group 1 consumed the least with an average per bird for the six-week period of 1.365 pounds of feed. Group 1 received no vitamin A supplement. As the vitamin A intake by groups increased, just so did the feed consumption. Group 4 receiving

EXPERIMENT E, TABLE X, Daily summary of weight and feed consumption in pounds by groups.

	Group 1		Group 2		Group 3		Group 4		Group 5	
Day	Weight	Feed	Weight	Feed	Weight	Feed	Weight	Feed	Weight	Feed
1	.074	.006	.078	.001	.072	.007	.074	.006	.069	.005
2	.070	.007	.074	.010	.072	.009	.077	.015	.072	.012
3	.080	.012	.083	.018	.076	.015	.091	.018	.080	.014
4	.090	.021	.097	.025	.087	.027	.097	.036	.082	.027
5	.101	.015	.120	.025	.109	.026	.111	.031	.102	.032
6	.106	.022	.133	.027	.124	.031	.144	.026	.113	.025
7	.127	.021	.145	.025	.140	.028	.152	.031	.123	.030
8	.135	.021	.167	.041	.149	.035	.171	.034	.132	.028
9	.147	.030	.183	.033	.172	.036	.187	.039	.151	.030
10	.158	.028	.203	.037	.185	.041	.210	.041	.159	.030
11	.175	.030	.223	.043	.210	.037	.242	.045	.172	.035
12	.190	.035	.247	.050	.222	.048	.250	.050	.192	.035
13	.210	.040	.267	.043	.250	.050	.272	.050	.208	.047
14	.230	.038	.280	.050	.275	.042	.297	.052	.230	.030
15	.250	.037	.306	.047	.302	.050	.327	.052	.245	.040
16	.280	.048	.333	.057	.322	.058	.350	.055	.257	.050
17	.302	.047	.367	.067	.357	.065	.377	.060	.290	.050
18	.320	.035	.393	.063	.385	.060	.412	.060	.310	.063
19	.337	.048	.413	.060	.410	.070	.432	.067	.345	.055
20	.357	.045	.443	.067	.442	.065	.465	.075	.365	.057
21	.380	.052	.460	.080	.462	.065	.500	.080	.392	.070
22	.402	.042	.497	.060	.490	.075	.530	.067	.425	.062
23	.420	.045	.513	.077	.520	.077	.562	.072	.438	.063
24	.422	.022	.553	.077	.560	.075	.575	.092	.472	.075
25	.450	.038	.593	.080	.585	.070	.622	.072	.507	.080
26	.462	.030	.620	.073	.600	.090	.667	.095	.545	.072
27	.523	.030	.647	.093	.622	.077	.697	.072	.565	.093
28	.547	.023	.690	.087	.650	.092	.712	.080	.612	.092
29	.533	.017	.713	.103	.710	.105	.750	.100	.642	.085
30	.533	.020	.753	.107	.687	.115	.782	.098	.647	.125
31	.527	.150	.793	.110	.737	.117	.810	.100	.700	.102
32	.565	.150	.830	.073	.802	.087	.855	.090	.732	.080
33	.550	.150	.837	.067	.837	.090	.887	.070	.775	.093
34	.535	.010	.830	.077	.855	.085	.875	.120	.790	.105
35	.535	.000	.813	.110	.822	.142	.887	.140	.835	.115
36			.883	.113	.910	.092	.915	.112	.858	.115
37			.913	.100	.872	.092	.935	.095	.877	.100
38			.947	.093	.900	.095	.975	.107	.892	.127
39			.980	.093	.952	.115	1.002	.090	.935	.102
40			1.007	.110	.992	.145	1.005	.157	.972	.110
41			1.020	.100	1.035	.102	1.060	.070	1.007	.128
42			1.027	.097	1.010	.105	1.055	.112	1.025	.162
43			1.077	.107	1.102	.122	1.050	.155	1.102	.127
Total feeds (lbs.)	1.365		2,876		3.030		3.079		2.988	
Total A units			1419		5157		7095			
Total feed, grams	619.16		1304.55 grams		1374.40 grams		1396.63 grams		1355.35	
A Units per 100 grams feed consumed			108.7		375.2		508.0			

the highest daily vitamin A intake consumed the greatest amount of feed with an average consumption per bird of 3.079 pounds.



Experiment E, comparative growth chart, 1935-36.

In a conversion of feed intake per bird to a gram basis and comparing this to vitamin A intake, we find Group 2 consumed 108.7 U.S.P. X units of vitamin A per 100 grams of feed. Group 3 consumed 375.2 units, and Group 4 consumed 508 units per 100 grams of feed.

Mortality during the experimental period was experienced only in Group 1, the vitamin A deficient group. All other groups completed the six-week period with 100 per cent livability. The chart illustrating growth curves of the various groups shows the periods at which deaths occurred in Group 1. One death occurred on the 26th day, one on the 31st day and two on the 35th day.

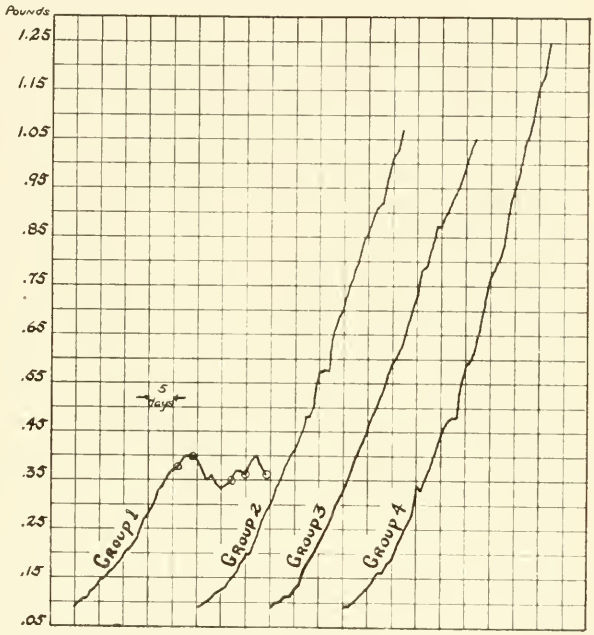
Experiment F.—1936-37

Procedure

Twenty pullet chicks derived from the cross of Barred Rock females with a New Hampshire male were used on test. Pedigree hatching of eggs from parent stock was resorted to in order that we might secure four female breeders having, after hatch, a group of at least five daughters. These chicks were then placed in four groups so that each group contained five chicks, one from each pedigreed female. By sorting chicks within groups on this basis more equality was obtained and variations between groups on vitamin A storage content of chicks from different parents was balanced among groups.

The source of vitamin A was a concentrate of carotene or pro-vitamin A possessing 3307 U.S.P.X. units of vitamin A per gram. The vitamin A content was secured substantially by a method advanced by H. R. Guilbert[5], whereby the carotene content is determined by methyl alcohol extraction and then transferred on the basis of .6 gamma carotene equal to one international unit of vitamin A. An 89 per cent methyl alcohol solution was used in place of the 85 and 92 per cent solutions recommended

by Guilbert. Acknowledgement is made of the service of C. K. Shuman, graduate assistant in agricultural chemistry, for his services in the chemical determination of vitamin A and the preparation of solutions. We wish also to acknowledge the courtesy of Purina Mills for supplying the carotene concentrate.



Experiment F, comparative growth chart, 1936-37.

The vitamin A concentrate was incorporated in Wesson oil in a homogeneous mass to provide solutions having a potency of 48, 98 and 158 international units per .4 cc. These solutions were then incorporated within the basal ration to provide 134.4, 274.4 and 442.4 international units per 100 grams of total feed. Feed was mixed fresh each week and kept in tightly sealed containers.

The basal ration consisted of 46 pounds ground white corn, 20 pounds ground wheat, 5 pounds wheat bran, 15 pounds dried skimmilk, 10 pounds meat scrap, 1 pound salt, 2 pounds calcium carbonate, and 1 pound irradiated yeast (400.000 U.S.P. units per pound.) The control group received basal ration only, with no addition of vitamin A.

All chicks were maintained in individual cages, developed at this station, throughout a period of 42 days. Daily weight and feed consumption records were kept for all individual chicks.

Discussion

The average growth curves for each lot are presented in diagrammatic form. It will be noted that the growth of groups 2 and 3, receiving 134.4 and 274.4 international units per 100 grams of feed, very closely parallel each other. The final weight at 42 days of age was substantially the same. Group 4 receving 442.4 int. units per 100 grams of feed paralleled the other curves up to approximately the 34th day when more rapid weight gains become evident. This action seems to indicate that there

is an additional demand by the chicks for vitamin A after the first five-week period. When this demand is met, more rapid and increased gains in weight will result.

The suggestion is here advanced that for rapid growth chicks with a normal storage of vitamin A upon hatching need during the first five-week period a total intake of approximately 134.4 international units of vitamin A per 100 grams of feed. Following this initial growth period the demands for vitamin A are increased to approximately 400 units per 100 grams of feed. Inasmuch as the experimental period extended only to 42 days, the limits of this second "demand" period are unknown. It seems logical to assume that other "increased demand periods" do exist as maturity increases. Sherwood and Fraps[14] state that fowls receiving the higher amounts of vitamin A (444 units) showed a larger weight, the differences appearing after the fourth month, indicating that stores of the vitamin A in the bodies of the fowls fed the smaller amounts (224 and 336 units) were beginning to be exhausted by that time.

The only mortality experienced during the experimental period occurred in the control group receiving the vitamin A deficient basal ration. The highest average weight recorded for the group was .40 pounds which occurred at 23 days of age. The growth of the "control" chicks closely paralleled that of the other groups up to ten days of age. After this period the depletion of vitamin A originally stored in the body of the chick was evidenced in less rapid growth. The occurrence of death of chicks in the control group is shown on curve by a small circle. Death in the control lot occurred at 21, 24, 32 and 39 days of age, respectively.

The results of this year's work were in harmony with those of the previous year's work except for one primary fact. Chicks receiving 508 U.S.P.X. units (1935-36) showed a reduction of weight gains following the fifth week. The work of this year was contradictory to this result inasmuch as the highest vitamin A unit fed group (442.4 int. units) showed increased gains after this period. To make for more exact trends and greater elimination of experimental error it is deemed necessary to materially increase the numbers of experimental birds in the various groups.

General Summary

1. The requirement for vitamin A by growing chicks is relatively large and becomes greater as maturity progresses.
2. The supply of vitamin A in the chick ration should preferably be from more than one source.
3. While there is some storage of vitamin A by chicks fed a well balanced feed, there is not enough stored to meet their requirements during a subsequent deficiency period of more than two weeks.
4. Too high a content of cod liver oil in feed will tend to decrease livability of chicks.
5. Kidney injury and presence of urinary crystals in feces and scrapings of large intestine accompanies vitaminosis A.
6. The feeding of increasing levels of vitamin A through periodic increases in per cent of cod liver oil is not warranted, providing the ration contains at least 1% cod liver oil of a potency of 2,000 vitamin A units per gram.

7. The New England College Conference ration (1932-33) contains sufficient vitamin A to prevent opthalmia and produce sufficient growth up to 12 weeks of age without the addition of vitamin A through the medium of cod liver oil.

8. Sardine oil and cod liver oil as used in these experiments when fed at 1/2 or 1% levels with a ration otherwise deficient in vitamin A supplied sufficient vitamin A to prevent the occurrence of vitaminosis A.

9. Somewhat more rapid growth was secured in the cod liver oil fed groups as compared to the sardine oil fed groups.

10. An increased vitamin A consumption tends to increase total feed consumed.

11. For rapid growth chicks with a normal storage of vitamin A upon hatching need during the first five-week period a total intake of approximately 134.4 international units of vitamin A per 100 grams of feed. Following this initial growth period the demands for vitamin A are increased to approximately 400 units per 100 grams of feed.

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